

SPATIAL DISTRIBUTION OF PLANKTONIC  
COPEPODA AND CLADOCERA IN RED ROCK  
RESERVOIR, IOWA, SUMMER, 1972

An abstract of a Thesis by  
Michael John McGrath  
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Drake University

The problem. The measurement of spatial distribution of Copepoda and Cladocera in Red Rock Reservoir, Iowa, summer, 1972, was undertaken. Water temperature, Secchi disk, and total water depth readings were also measured.

Procedure. Volumetric samples of free-swimming zooplankton were collected at weekly intervals from June 6 to September 8, 1972. Collections were made at three stations on each of four transects representing different areas of the reservoir. Samples were obtained from one meter intervals from the surface to three meters.

Findings. Water temperature varied from a low of 18.5°C to a high of 30.0°C. Secchi disk readings ranged from 6 to 70 cm. Maximum readings were obtained near the dam and decreased towards the headwaters. Retention time varied from 3.9 to 55.6 days with a study mean of 10.7 days. A gradual increase in zooplankton numbers was noted from June 16 until a high was reached on July 5 (356 organisms per liter). The numbers then rapidly decreased until a low was reached on August 15 (0 organisms per liter). The dam transect always had the highest numbers of organisms with headwater transects having lower numbers of organisms. Eight species of zooplankton were identified during the study.

Conclusions. Highest zooplankton populations occurred near the dam with smaller numbers present up reservoir. Numbers of zooplankton per liter and retention times were lower than during a 1970 study. Retention time was the main controlling factor on zooplankton development. No correlations were found between zooplankton numbers and temperature, light penetration, and depth.

Recommendations. More station sites and more frequent sampling could enable the study of horizontal distribution of zooplankton. Monitoring reservoir inflow and outflow would enable the determination of population development within the reservoir. The interaction of zooplankton with phytoplankton and macrophytes should be investigated.

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COPEPODA AND CLADOCERA IN RED ROCK  
RESERVOIR, IOWA, SUMMER, 1972

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A Thesis  
Presented to  
The School of Graduate Studies  
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In Partial Fulfillment  
of the Requirements for the degree  
Master of Arts

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by  
Michael John McGrath  
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by

Michael John McGrath

Approved by Committee:

P. J. Longshurz  
Chairman

Wayne B. Medley

Laurence E. Brown

Dean of the School of Graduate Studies

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## INTRODUCTION

Gerking (1963) lists Iowa as a typical mid-continent state and describes its geographical characteristics: previously glaciated plains, rainfall 18 to 30 inches per year, "pot and kettle" terrain in north central Iowa, warm summers, strong winds, arid periods, deluge rainfalls, floods, largely agricultural, and with lakes frozen about five months per year. Reservoirs and farm ponds are prominent and there are numerous bodies of water in the state. They display eutrophic features due to inundation of crop and forested land (Gerking, 1963). Thus oxygen depletion, high temperatures, plankton blooms, warm water fish populations, and thermal stratification are found. Siltation and turbidity cause serious problems in many impoundments by reducing productivity due to reduced light penetration.

During the last quarter of a century man has vastly changed the landscape of the Midwest. The U. S. Army Corps of Engineers has built a series of dams and reservoirs which have had a direct effect on the ecosystems of several streams and river systems. Within Iowa three reservoirs (Coralville, Rathbun, and Red Rock) have been completed while a fourth (Saylorville) is scheduled for completion in 1975. The main functions of these structures are flood control and maintenance of downstream flow during periods of low water.

Although the general limnology of these reservoirs is known, certain aspects of the spatial distribution of zooplankton remain unknown.

Of the major portion of limnological data on seasonal and vertical planktonic distribution most has either been studied qualitatively or secondarily (Ruttner, 1964). An established fact concerning horizontal distribution is its irregularity when any area of fair size is considered. This lack of uniformity occurs not only in large areas but also in small lakes or small regions of large lakes (Welch, 1952). Phytoplankton appear to have a more uniform distribution than zooplankton. Zooplankton have shown some great irregularities in distribution which have not been correlated to date with any known feature of the environment. Temporary conditions which are quickly altered or destroyed by resumption of horizontal turbulent currents can produce lasting differences in plankton composition. Moberg (1918) studied horizontal distribution over comparatively small distances and recorded considerable diversity of zooplankton numbers in Devils Lake, North Dakota.

Zooplankton of the hypolimnion have been found to be quite different from that inhabiting the epilimnion (Hutchinson, 1967). Superdispersion does not increase with distance (Ricker, 1937). For individual zooplankton stages the usual pattern is one of infradisersion caused by competition for food and the disruption of randomness by sexual

attraction of the spaced pattern produced by this food competition (Hutchinson, 1967).

Food availability has been shown to affect distribution by numerous workers (Welch, 1952; Hutchinson, 1967). Phytoplankton, through competition, decrease zooplankton numbers. However if phytoplankton is a food source, increases in phytoplankton produce zooplankton increases (Ryther, 1954; Anderson, Comita, and Engstrom, 1955; Edmondson, Comita and Anderson, 1962). Chandler (1939), Reif (1939), Hasler and Jones (1949), and Baylor and Smith (1953) found dense growths of large aquatic plants had an inhibiting effect upon zooplankton. Predation by fish, zooplankton, or other aquatic organisms also has an effect upon zooplankton distribution by reducing numbers (Hutchinson, 1967).

A major consideration in horizontal and spatial distribution of zooplankton is physio-chemical effects of the aquatic system (Tryon and Jackson, 1952). However a change in external conditions may have no effect within a particular depth stratum (Ruttner, 1964). Suspended organic matter has been shown to affect spatial distribution of zooplankton by increasing their numbers (Tryon and Jackson, 1952; Saunders, 1957; Hartman and Himes, 1961). Welch (1952) reviewed spatial distribution of zooplankton with respect to the pH of a lake system and found changes in species and numbers when the pH is either high or low. Dissolved oxygen was found to affect some zooplankton (Hazelwood and Parker, 1963).



Borecky (1956) and Hazelwood and zooplankton distribution correlated with salinity of ions. High numbers often related to specific conductivity.

Studies by Armitage (1961 (1963), Hall (1964), and Parr (1964) indicate that the higher the temperature until an upper temperature tolerance is reached, the greater the population development. Coker (1940), Welch (1952), and others have shown that effects of wind upon distribution or infradispersion occur. Penetration (and photoperiod) has a marked effect on spatial distribution, the higher the temperature, the greater the population development (Armitage, 1963; Stavn, 1971). Currents of distribution and workers have related to salinity (Welch, 1952). Lagmuir spirals have caused by wind (Hutchinson, 1967).

Cushing (1964), Hanebrink and Asch (1971) found that standing water reservoirs usually increased and turbidity were markedly reduced. They concluded that convergences act as traps. Cowell (1967, 1970), Dickman (1967) found that standing crops of plankton

as rate of water exchange increased. According to Brook and Woodward (1956) water exchange rate must be greater than 18 days for significant development of zooplankton populations. Ruttner (1964), Hutchinson (1967), Schmidt (1968) have reviewed the effects of shore avoidance and marked water level fluctuations and showed that zooplankton actively avoid shore. Cowell (1970) found a minimum size standing crop during a low storage time of 7-8 days but showed an increase in standing crop size as storage time increased (maximum of 23 days).

Each lake or reservoir must be taken individually as a problem with peculiar chemical, physical, and planktonic characteristics which cause it to be unique (Schmidt, 1968). Since water resource management and water quality are becoming vitally important, and since planktonic organisms are an important link in aquatic food webs and possibly reflect the quality of the water, the factors controlling spatial distribution of zooplankton need to be known, only with this understanding can intelligent management of aquatic resources be achieved (Hairston, 1959).

The objectives of the current study were to:

1. Determine the extent of horizontal and longitudinal distribution of zooplankton within Red Rock Reservoir.
2. Determine the effect of reservoir retention time on zooplankton populations.
3. Determine the interrelationships of temperature and turbidity on zooplankton populations.

4. Compare the present species composition of the reservoir with previous studies.

## MATERIALS AND METHODS

### The Study Area

Red Rock Reservoir is located in central Iowa, approximately eight kilometers north of Knoxville and is a U. S. Army Corps of Engineers flood control project on the Des Moines River. Under normal river conditions the conservation pool extends 18.2 km upstream from the dam and has a surface area of 3,623 hectares at an elevation of 221.0 m above sea level. The mean depth of the reservoir is 3.1 m. The primary objective of the reservoir is to store excessive run-off to prevent flooding until such a time as a gradual release of water can be accomplished.

Four transects were selected to divide the conservation pool into approximately three equal parts (Fig. 1). Transect 1 was located through the deep water area near the dam. Transects 2 and 3 were located near the middle of the reservoir and approximately 2.7 km apart. Transect 4 was located in the upper end of the reservoir approximately 1.0 km downstream from the Highway 14 bridge. Each transect was divided into three sampling stations: two were approximately equi-distant from either shore and the third was in the approximate center of the reservoir for a total of twelve

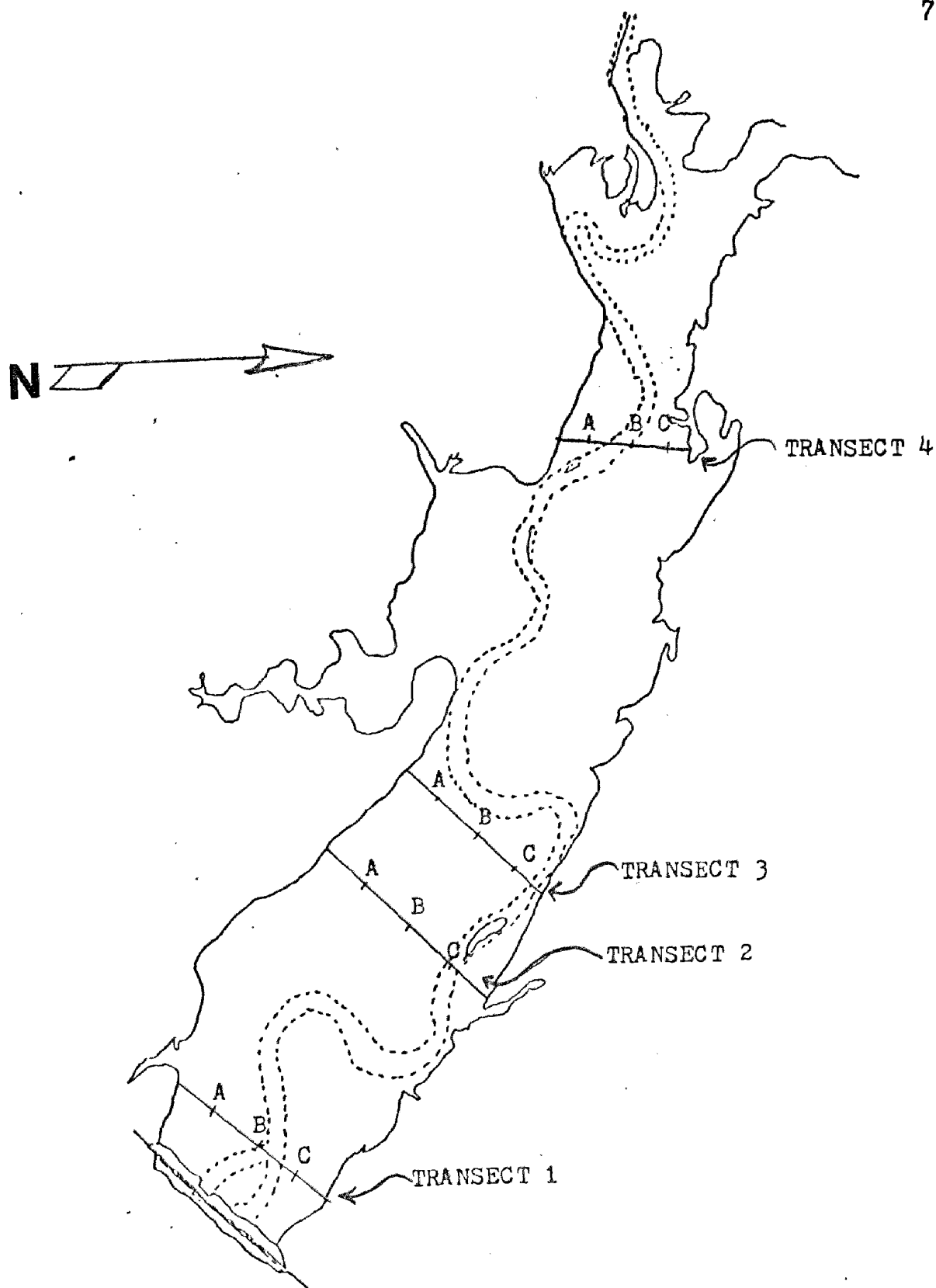


Figure 1. The location of the stations and transects on Red Rock Reservoir, Iowa, Summer, 1972.

sampling stations. Each station was sampled at four depths: 0 m, 1 m, 2 m, and 3 m (where water depth permitted).

### Procedures

From 6 June to 8 September 1972, volumetric samples of free swimming zooplankton were collected at weekly intervals between 10 AM and 3 PM. Samples were collected with a 3.1 liter Kemmerer water bottle. The valves were released as soon as the sampling depth was reached. Kemmerer samples from each depth were concentrated by emptying the contents into a conical No. 20 mesh plankton net with attached vial. Organisms were washed from the net into the vial by partially dipping the net into water. Samples were preserved in ten percent formalin and returned to the laboratory for examination.

Physical measurements taken at each station included: (1) the temperature at each sampling depth using an electrical resistance thermometer, (2) light penetration using a 20 cm Secchi disc, and (3) total water depth.

In the laboratory the contents of each plankton sample were placed in a gridded plastic petri dish for enumeration and genus identification using a dissecting microscope. Species were determined under high power on semi-permanent slides using Brooks (1959), Yeatman (1959), and Wilson (1959) as reference authorities. All sample counts were transformed by appropriate calculations into organisms per

liter for each sample.

## RESULTS

### Physical and Chemical Data

Water temperatures recorded at each station are shown in Appendix A. During the study water temperature varied from a low of 18.5°C on 30 June to a high of 30°C on 25 July. Slightly higher temperatures occurred at the surface with little variation occurring between 0 and 3 meters. Lower temperatures were occasionally found at the headwaters (transect 4) on sampling dates. At times water depth at some stations was insufficient to obtain temperature readings from all depths.

Secchi disc readings (Appendix B) ranged from 6 to 70 cm. The maximum readings for each sample day occurred at transect 1 near the dam and decreased towards the headwaters with the low readings at the headwaters transect (transect 4). The low values followed a period of rainfall and coincided with a decreased retention time.

Retention times were calculated according to Clark (1972). Retention time (flushing rate) varied from 2.8 days in mid-August to a maximum of 55.6 days in early June (Figure 2). During the majority of the study the retention times were low. Through the period from 28 June to 18 July, values ranged from 10.8 to 14.7 days. From 19 July to 1 August

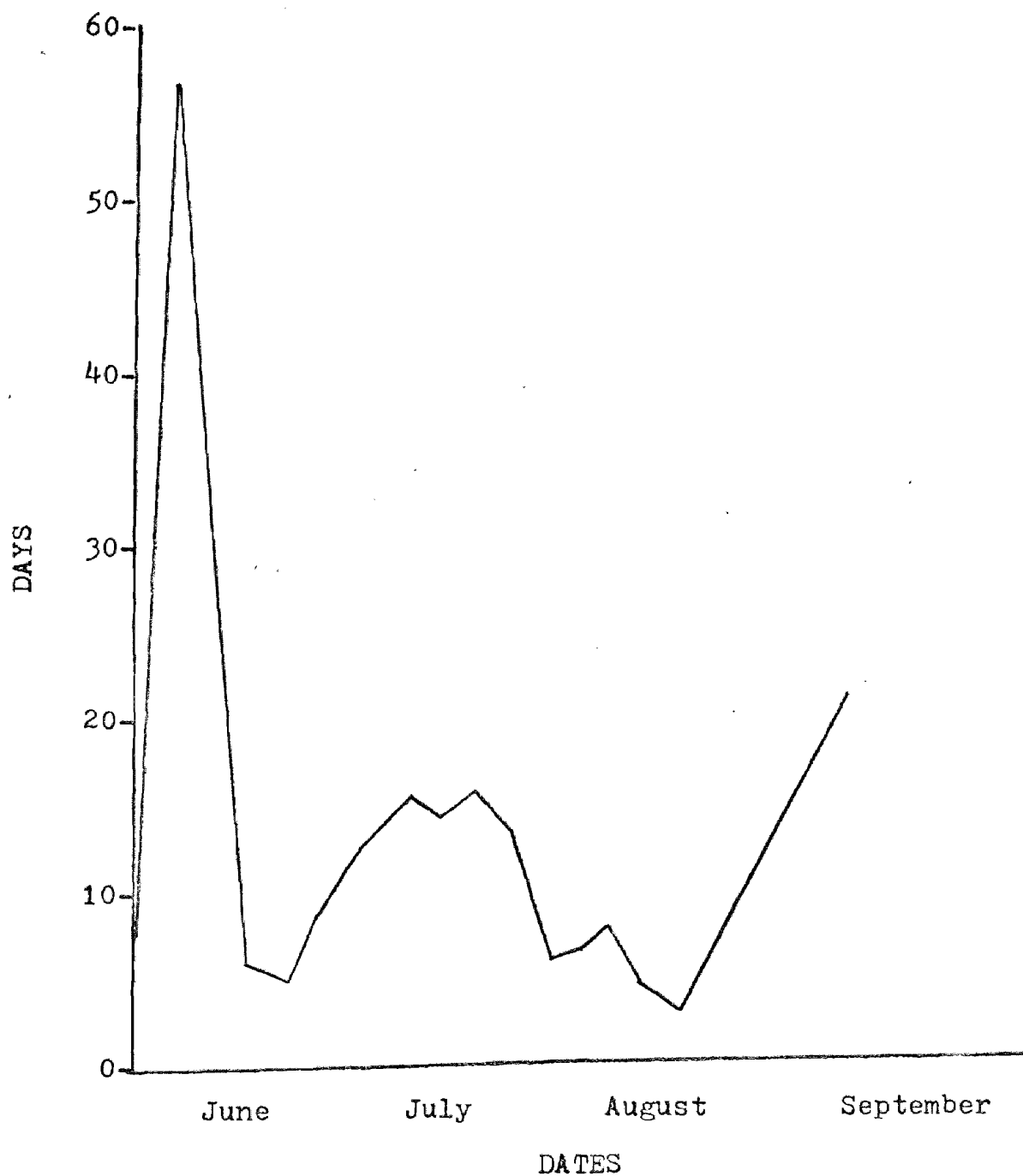


Figure 2. Mean retention time (days) of Red Rock Reservoir, Iowa, Summer, 1972.

values ranged from 4.0 to 6.1 days. From 7 August to 7 September values ranged from 2.8 to 21.0 days. The calculated average retention time for the study period was 10.7 days.

### Biological Data

A gradual increase in mean zooplankton numbers per transect was noted from 16 June until a high was reached on 5 July (191 organisms per liter) (Table 1, Figure 3, and Appendix C). The numbers then rapidly decreased until a low was reached on 15 August (1 organism per liter). During the July peak, station C of the two deepest transects (1 and 2) had 169 and 101 organisms per liter, with B having 208 and 94 organisms per liter, and A having 167 and 86 organisms per liter. In the two shallow transects (3 and 4) during the July peak, station B had 83 and less than 1 per liter, with C having 61 and 20 per liter, and A having 30 and 2 per liter. During the July peak transect 1 had the highest mean numbers (191 per liter) and a decrease was noted in transects 2 and 3 (94 and 58 per liter) with the lowest numbers occurring at transect 4 (7 per liter). Figure 4 illustrates zooplankton population development in the reservoir from 30 June to 18 August, 1972. A general trend exhibited was low numbers at the headwaters and high numbers towards the dam. Population numbers increased rapidly between 30 June and 5 July and declined less rapidly between 14 July and 18 July. On 5 July



Table 1. Transect means (number per liter), variance, and standard error of zooplankton collected per transect, Red Rock Reservoir, Iowa, Summer, 1972. Numbers in parentheses represent the number of samples taken if less than 12.

	I	II	III	IV
June 16- $\bar{x}_2$	11.25	5.28	3.68	5.21
$s^2$	46.85	6.51	2.65	0.36
$s_x$	3.42	1.28	0.81	0.30
June 22- $\bar{x}_2$	8.61	5.63	3.40	(10)3.33
$s^2$	3.45	0.49	0.07	13.13
$s_x$	0.93	0.35	0.13	1.81
June 30- $\bar{x}_2$	21.60	19.52	11.73	(9)1.39
$s^2$	69.18	86.29	52.83	2.43
$s_x$	4.16	4.64	3.63	0.78
July 5- $\bar{x}_2$	190.76	93.54	57.64	(10)7.00
$s^2$	2566.08	1325.93	696.50	131.64
$s_x$	25.33	18.21	13.20	5.74
July 14- $\bar{x}_2$	160.21	64.72	(11)41.29	(10)14.42
$s^2$	3218.55	1383.43	1125.91	214.00
$s_x$	28.37	18.60	16.78	7.31
July 18- $\bar{x}_2$	59.66	44.38	(11)17.35	(9)4.17
$s^2$	1750.45	1944.93	209.92	20.84
$s_x$	20.92	22.05	7.24	2.28
July 25- $\bar{x}_2$	7.15	4.38	2.50	(10)2.42
$s^2$	53.03	7.62	3.04	7.63
$s_x$	3.64	1.38	0.87	1.38
Aug. 7- $\bar{x}_2$	5.47	3.00	2.55	1.81
$s^2$	9.31	1.06	2.68	1.20
$s_x$	1.53	0.51	0.82	0.55
Aug. 15- $\bar{x}_2$	1.72	0.96	2.14	(11)2.19
$s^2$	1.50	0.50	1.69	7.98
$s_x$	0.61	0.35	0.65	1.41
Aug. 27- $\bar{x}_2$	17.45	12.01	7.35	(8)0.47
$s^2$	37.39	21.04	7.09	0.45
$s_x$	3.06	2.29	1.33	0.34
Sept. 7- $\bar{x}_2$	(11)13.10	12.03	9.12	(8)1.53
$s^2$	42.62	31.08	2.46	2.99
$s_x$	3.26	2.79	0.78	0.86

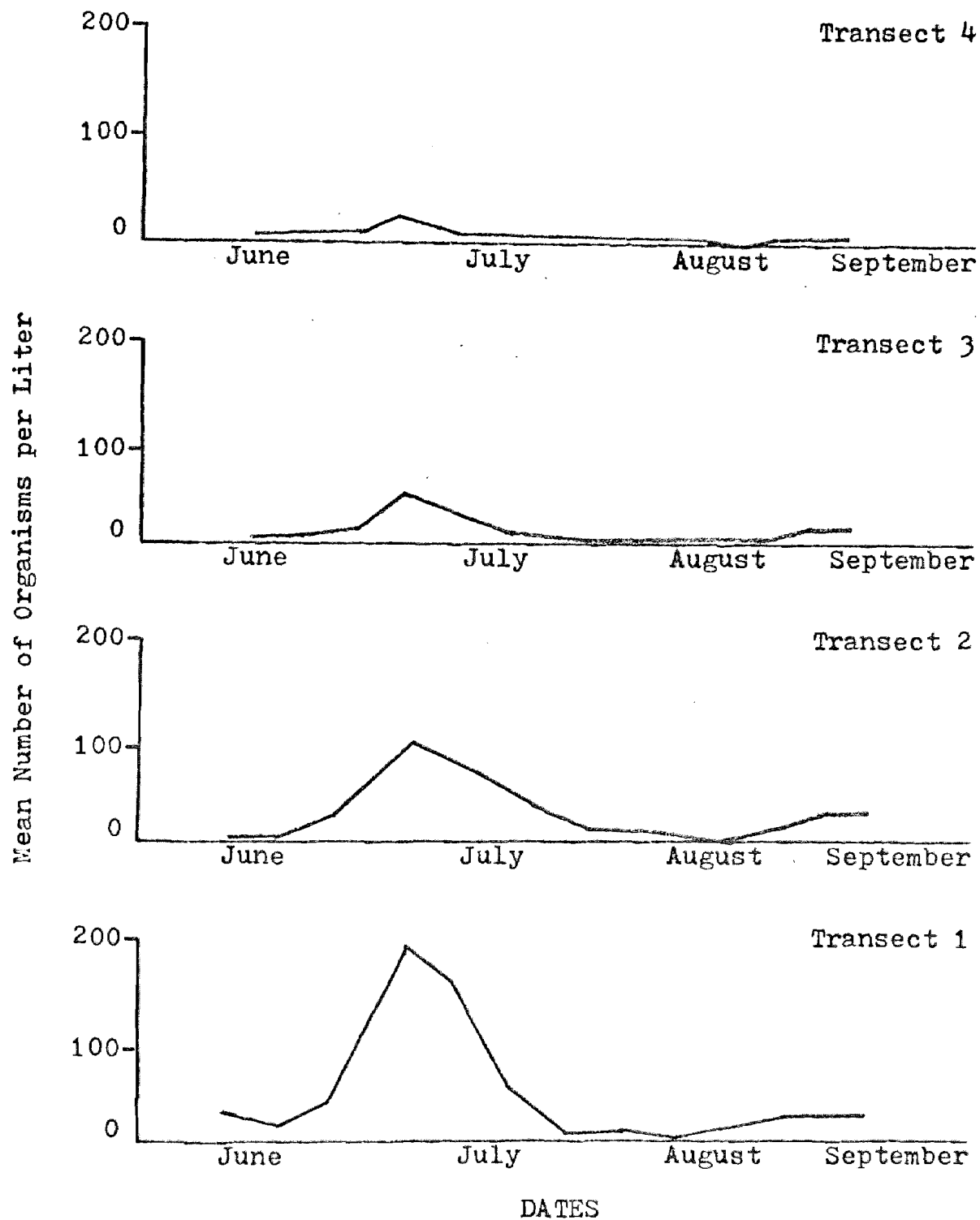


Figure 3. Mean number of organisms per liter for each transect in Red Rock Reservoir, Summer 1972.

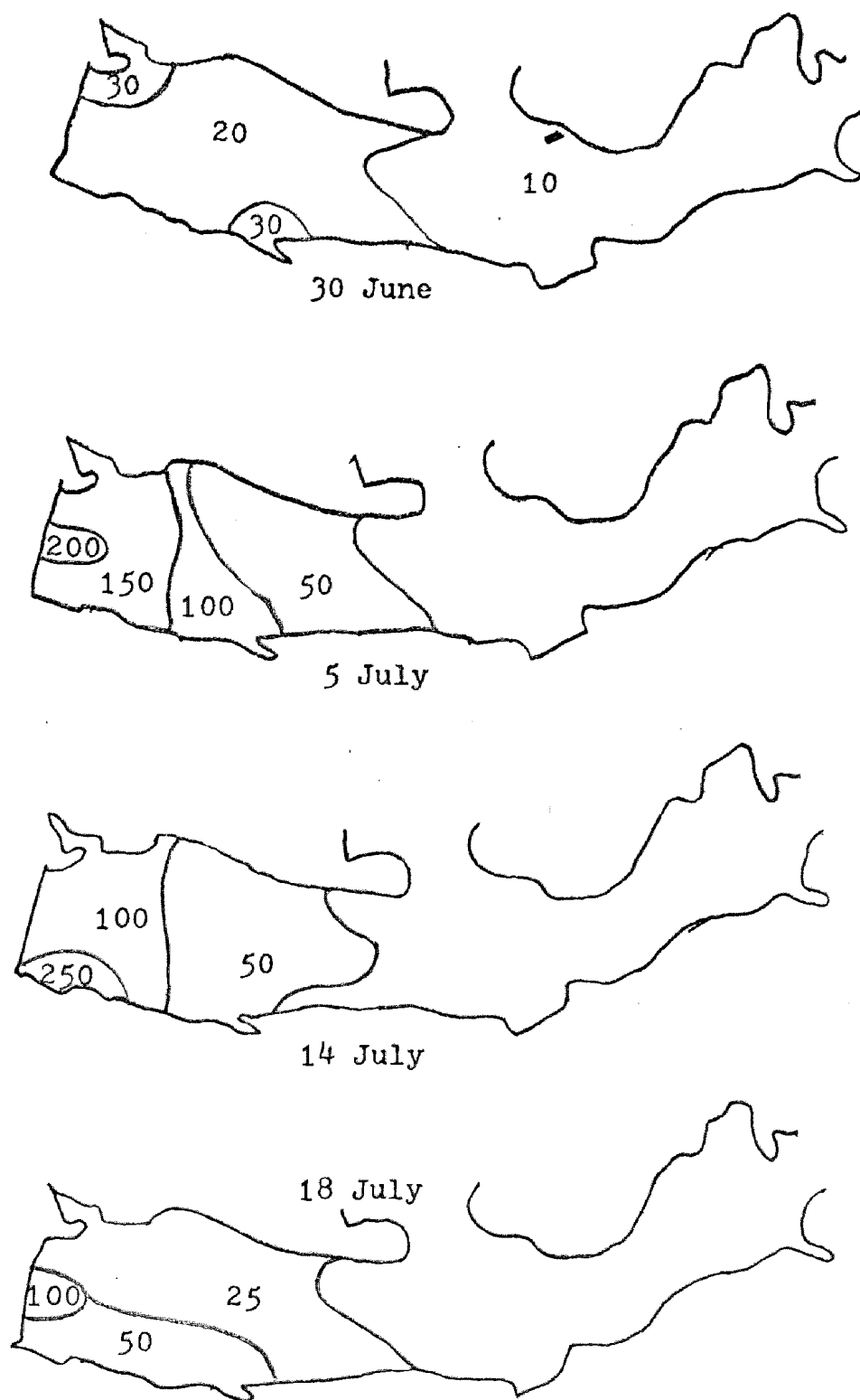


Figure 4. Representative sampling dates showing abundance distribution (numbers per liter per station) between 30 June and 18 July at Red Rock Reservoir, Iowa, Summer, 1972.

and 14 July, higher numbers occurred near the dam and along the north edge of the reservoir.

Eight species of zooplankton were identified during the study (Table 2). Bosmina had an early population bloom in late June (30 per liter) when other forms were scarce (10 or less per liter) and then peaked in mid-July (106 per liter). Cyclops peaked in the middle of July (298 per liter) and then were scarce (20 or less per liter) for the remainder of the study. Calanoids were never numerous during the study. The high level of calanoids was reached in mid-July (20 per liter). Diaphanosoma was the dominant cladoceran (30 per liter) following the Bosmina peak. After the 5 July peak was reached Moina became more numerous (44 per liter) than Diaphanosoma which decreased (10 or less per liter). Near the end of August, Daphnia sp. became more numerous (15 per liter) and Moina decreased.

Ten replicate zooplankton samples were taken on 7 September at station B transect 1. The mean number of organisms per liter was 34.65 with a standard deviation of 2.49 and a standard error of 0.79. The coefficient of variation was 7.19%.

Table 2. List of species of Copepoda and Cladocera occurring in Red Rock Reservoir, Iowa, Summer, 1972.

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Copepoda: Cyclopodia

Cyclops bicuspidatus thomasi S. A. Forbes 1882.

Copepoda: calanoida

Diaptomus siciloides Lilljeborg 1889.

Cladocera

Bosmina longirostris (D. F. Muller) 1785.

Ceriodaphnia quadrangula (D. F. Muller) 1785.

Daphnia ambigua Scourfeld 1947.

Daphnia pulex Leydig 1860 emend. Richard 1896.

Diaphanosoma brachyurum (Lieven) 1848.

Moina micrura Kurz 1874.

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## DISCUSSION

Rainfall in the reservoir watershed was high during the study period and caused low retention times. These two factors apparently prevented the development of the high population level as reported by Asch (1971). Thus population levels during the study period were abnormally low.

An examination of the data in Appendix C shows that two-thirds of the time variance ( $S^2$ ) was greater than the mean ( $\bar{X}$ ). This means that the zooplankton populations showed superdispersion (Cassie, 1962). Thus zooplankton populations were distributed non-randomly which is consistent with the idea expressed by Hutchinson (1967) that superdispersion exists in plankton populations more frequently than infra-dispersion.

In the shallow area of the reservoir, zooplankton appeared to be most numerous at the deeper stations of each transect. This distribution could be attributed to: (1) littoral avoidance by zooplankton, and (2) infradisersion due to currents and wind. In the deeper two transects, zooplankton were most numerous at stations shoreward of the predominantly southern winds (Figure 4). Berzins (1958) and Hutchinson (1967) found that planktonic species avoided the littoral area. Welch (1952) mentioned planktonic avoidance of shallow shore areas possibly because of a stimulus emanating from the shore or the shallow bottom. Ruttner (1964)

stated that avoidance of shore may be due to a negative rheotropism.

In the headwaters area of the reservoir with a somewhat restricted width, organisms were found away from the shallow depth stations presumably due to the same shore avoidance reaction. Patalas (1969) noted wind as a factor in planktonic distribution. Grover and Coker (1940) and Parr (1967) found that wind action concentrated planktonic distribution and that streaking occasionally occurred. Streaking of zooplankton and phytoplankton was observed in the study.

Welch (1952) stated that wind action upon surface waters concentrated plankton near the shore. Stavn (1971) reported that currents concentrated the distribution of plankton. In the dam area, stations in proximity to the dam had lower numbers of zooplankton than shoreward stations. A possible mechanism causing this phenomenon is current avoidance and/or current concentration of zooplankters due to the current from the outflow of water through the dam watergates.

The deeper the total depth of the transect, the higher the zooplankton population numbers. Thus, damward transects had higher numbers than did transects nearer the headwaters. This could be explained by increased turbidity and decreased light penetration as one approached the headwaters. Several workers supporting this conclusion are Hazelwood and Parker (1963) on light penetration, Saunders (1957) and Tryon and

Jackson (1952) on suspended organic matter, and Hartman and Himes (1961) on silt concentration.

Schmidt (1968) found that marked water level fluctuations of Coralville Reservoir obliterated zooplankton population differences between deep and shallow areas. Cushing (1964) found that standing crops of zooplankton in reservoirs usually increased damward because currents and turbidity were markedly reduced. Currents were not measured in this study but light penetration was always greater at the dam area than at the headwaters area indicating that turbidity was less at the dam area. This would affect the zooplankton population by causing higher numbers in the dam area. This is what was found during the study.

Retention time data correlated well with population data. The higher the retention time the larger the zooplankton population. On 5 July, the mean population high was 191 organisms per liter (transect 1) with a retention time of 13.5 days. On 14 July, the mean population high was 160 organisms per liter (transect 1) with a retention time of 13.5 days. On 18 July, the mean population high was 60 organisms per liter (transect 1) with a retention time of 11.5 days. Cowell (1967, 1970) found that standing crops of zooplankton were influenced significantly by water exchange rate. The more rapid the exchange rate the lower the standing crop values; however, Johnson (1964) found this relationship to be non-linear. A slightly lower retention time



could drastically reduce zooplankton levels.

A regression analysis was done to determine the influence of the retention time of the period preceeding the collection day on the mean number of organisms/liter collected on that day for all transects. The significant F value for the 0.05 (1,9) level is 5.12; the analysis of variance gave a value of 10.56 which would show that retention time must be considered to have a significant influence on zooplankton numbers. For example, in this study a reduction of water retention time from 13.5 to 11.5 days was paralleled with a zooplankton standing crop reduction from 160 to 60 organisms per liter.

Dickman (1969) reported that the low standing crop in his study was due to cropping of the zooplankton via the reservoir outlet; population numbers were also found to be inversely related to the rate at which water entered the system. Brown (1969) found rainfalls to be the cause of a high flushing rate which reduced standing crops. Brook and Woodward (1956) and Asch (1971) found that the water exchange rate must be greater than 18 and 11 days, respectively, to avoid this phenomenon. Johnson (1969) found 15 days to be the crucial time limit for zooplankton development.

Low retention times and marked shifts of water level may have prevented normal population development during the study, such as was found by Schmidt (1968) at Coralville Reservoir. Asch (1971) reported population levels of 80

organisms per liter in Red Rock Reservoir with an average retention time of 11.2 days. This study found average population levels of 40 organisms per liter with an average retention time of 10.7 days.

Temperature differences between stations did not influence populations in this study. Each transect was relatively homogeneous for temperature and light penetration during sample periods. However, headwater transects always had a lower light penetration than did dam area transects. Retention time appeared to be associated with the turbidity levels found. That is, when retention time was high, turbidity was low and vice versa.

The number of species occurring June through September decreased from nine species in 1970 (Asch, 1971) to eight species during this study. Seven of the same species were found in both studies. Species found dominant in the summer by Asch were also dominant during this study. All species found were typical reservoir species.

#### SUMMARY AND CONCLUSIONS

Volumetric samples of free-living zooplankton were taken at Red Rock Reservoir, Iowa, in the summer of 1972. A distinct longitudinal gradient in numbers of organisms per liter and also in Secchi disc readings was found. High values for both items occurred at the dam transect. The

retention time (flushing rate) was the main factor controlling population development. Eight species of zooplankton were collected and identified.

A study with more frequent sampling would give a more detailed population profile. Additional transects with additional sample depths where possible would aid in delineating the population profile. The inflow and outflow areas of the reservoir could be monitored for possible influences on population development. Interactions of zooplankton with phytoplankton and macrophytic plants should be investigated.

The following conclusions were drawn from this study:

1. Numbers of zooplankters were greatest at the dam transect and numbers decreased towards the headwaters.
2. Number of zooplankters and retention time was found to be less in this study than in a 1970 study. In general, species during both studies were the same.
3. Retention time (flushing rate) was the main controlling factor on zooplankton development.
4. The effect of temperature and light penetration on zooplankton populations could not be determined because of low population numbers, small amounts of variation in temperature and light, and the masking influence of retention time.

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Appendix A. Water temperature ( $^{\circ}\text{C}$ ) per each depth in Red Rock Reservoir, Iowa, Summer, 1972. (- no values taken, \* water depth insufficient)

Transect	Station	Depth	Sample day									
			6/16	6/22	6/30	7/5	7/14	7/18	7/25	8/7	8/15	8/27
I	A	0	22.5	20.0	22.0	21.5	25.0	25.0	29.5	24.0	27.0	24.0
I	A	1	23.0	20.0	21.5	21.5	25.0	25.0	29.0	23.5	26.5	24.0
I	A	2	22.9	20.0	20.8	21.8	25.0	24.5	28.0	23.5	23.2	24.0
I	A	3	22.5	20.0	20.5	21.2	25.0	24.0	27.5	23.5	22.5	24.0
I	B	0	23.2	20.2	22.0	22.0	25.0	25.0	29.8	24.0	27.0	24.0
I	B	1	22.8	20.0	21.8	21.8	25.0	24.5	29.0	23.8	23.5	24.0
I	B	2	22.8	20.0	21.5	20.8	24.5	24.0	28.0	23.5	22.5	24.0
I	B	3	22.5	20.0	21.5	21.5	24.5	24.0	28.0	23.5	22.0	24.0
I	C	0	23.0	19.5	22.0	22.5	25.5	25.5	29.8	24.0	28.8	24.0
I	C	1	22.5	19.5	21.0	21.8	25.0	25.0	29.0	24.0	25.5	24.0
I	C	2	22.5	19.5	21.0	21.5	25.0	24.5	28.0	23.8	23.5	24.0
I	C	3	22.5	19.5	21.0	20.8	25.0	24.0	27.5	23.5	22.5	24.0
II	A	0	21.0	--	24.2	23.8	27.0	26.0	30.0	23.5	28.0	24.0
II	A	1	22.0	--	23.5	22.8	26.0	24.5	29.0	23.5	25.5	23.5
II	A	2	22.2	--	22.5	22.0	25.0	24.0	28.0	23.0	23.8	23.0
II	A	3	22.0	--	22.0	21.2	25.0	24.0	28.0	23.0	22.5	23.0
II	B	0	22.0	--	20.5	25.0	27.5	26.0	30.0	23.5	28.5	24.0
II	B	1	21.5	--	23.2	23.0	26.0	25.0	29.5	23.0	27.0	24.0
II	B	2	21.7	--	22.0	22.0	25.5	24.0	28.5	23.0	22.5	23.0
II	B	3	21.7	--	21.8	21.5	25.0	24.0	27.5	22.2	22.2	23.0
II	C	0	21.7	--	21.5	24.0	27.5	26.0	30.0	23.5	28.5	23.5
II	C	1	21.8	--	21.0	22.8	26.0	24.5	29.5	23.0	26.5	23.5
II	C	2	21.8	--	20.5	22.2	26.0	24.5	28.5	23.0	24.0	23.0
II	C	3	21.6	--	20.5	22.2	26.0	24.0	28.0	23.0	22.0	23.0



Appendix A. (Continued)

Transect	Station	Depth	Sample day									
			6/16	6/22	6/30	7/5	7/14	7/18	7/25	8/7	8/15	8/27
III	A	0	23.5	--	21.8	24.5	28.0	25.0	29.5	24.0	26.5	23.0
III	A	1	23.0	--	21.0	23.0	27.0	24.5	29.0	23.5	24.5	22.5
III	A	2	22.0	--	20.2	22.0	27.5	24.0	28.0	23.0	23.5	22.0
III	A	3	22.0	--	18.8	21.2	*	*	28.0	22.5	23.0	22.0
III	B	0	22.5	--	21.0	24.0	28.0	26.0	29.0	24.0	27.5	23.0
III	B	1	22.5	--	19.5	23.0	26.0	24.0	29.0	23.0	26.0	23.0
III	B	2	22.0	--	19.2	21.8	26.0	24.0	28.0	23.0	23.0	23.0
III	B	3	21.5	--	19.0	21.5	25.5	24.0	28.0	22.0	22.5	23.0
III	C	0	22.0	--	22.0	22.5	28.0	26.0	29.0	24.0	28.0	23.5
III	C	1	22.0	--	21.5	21.5	26.5	24.0	28.5	23.5	26.0	23.0
III	C	2	22.0	--	20.0	21.0	26.0	24.0	27.5	23.0	23.5	23.0
III	C	3	21.5	--	20.0	21.5	25.5	24.0	27.2	23.0	22.0	23.0
IV	A	0	21.5	22.0	23.5	22.0	26.0	25.0	26.0	22.0	26.0	22.5
IV	A	1	21.5	21.5	23.0	21.8	26.0	23.8	26.0	22.0	24.5	22.5
IV	A	2	21.5	21.0	23.0	22.0	25.5	*	26.0	21.5	23.5	*
IV	A	3	21.5	21.0	*	*	*	*	*	21.0	22.5	*
IV	B	0	21.5	22.0	24.0	21.0	26.0	24.0	23.0	22.0	26.5	22.0
IV	B	1	21.5	21.0	23.8	20.8	26.0	24.0	23.0	22.0	25.0	22.0
IV	B	2	21.5	20.0	23.5	20.5	26.0	24.0	23.0	22.0	23.5	22.0
IV	B	3	21.5	*	23.0	20.5	26.0	23.8	22.5	22.0	21.0	22.0
IV	C	0	22.0	22.0	24.0	21.5	26.0	24.5	26.0	22.0	27.0	22.5
IV	C	1	22.0	20.0	24.0	20.5	26.0	23.2	25.5	21.5	24.0	22.5
IV	C	2	21.5	20.0	24.0	20.8	25.0	*	25.5	21.5	23.0	*
IV	C	3	*	*	*	*	*	*	*	21.5	*	*
Air			23.0	19.5	23.0	22.0	22.0	23.0	25.5	25.8	33.0	29.0

Appendix B. Secchi Disk readings (cm) per each station occurring in Red Rock Reservoir, Iowa, Summer, 1972.

Transect	I	I	I	II	II	II	III	III	III	IV	IV	IV
Station	A	B	C	A	B	C	A	B	C	A	B	C
June 16	30	30	32	20	23	25	25	20	20	15	23	23
June 22	25	30	27	20	25	23	15	22	25	15	15	15
June 30	70	60	50	45	45	60	40	30	30	25	25	20
July 5	40	37	40	45	43	40	25	42	42	25	23	20
July 14	75	70	67	55	65	52	45	50	40	25	20	25
July 18	55	50	45	40	50	55	33	32	30	18	20	21
July 25	40	40	50	35	35	40	35	35	40	20	20	20
August 7	20	20	20	17	18	18	15	18	18	6	8	8
August 15	60	63	70	45	65	63	42	45	55	37	33	35
August 27	21	21	25	23	18	18	18	20	10	15	12	15

Appendix C. Mean number of organisms/liter for each depth of each transect with variance and standard error in Red Rock Reservoir, Iowa, Summer, 1972.

\* - n = 2  
@ - n = 1

Transect	I	II	III	IV
June 16				
0m $\bar{x}_2$	6.39	8.33	3.06	4.45
s	9.95	46.54	3.71	4.39
s <sub>x</sub>	1.82	3.94	1.11	1.21
1m $\bar{x}_2$	21.39	6.39	5.00	5.55
s	558.39	55.77	8.31	8.59
s <sub>x</sub>	13.66	3.94	1.66	1.69
2m $\bar{x}_2$	8.89	2.78	5.00	5.83
s	9.95	1.62	4.87	2.11
s <sub>x</sub>	1.82	0.73	1.27	0.84
3m $\bar{x}_2$	8.33	3.61	1.67	5.00
s	9.07	4.39	2.77	2.11
s <sub>x</sub>	1.74	1.21	0.96	0.84
June 22				
0m $\bar{x}_2$	6.11	6.66	3.61	3.89
s	4.39	33.37	16.89	28.70
s <sub>x</sub>	1.21	3.34	2.37	3.09
1m $\bar{x}_2$	9.72	5.00	3.05	5.83
s	3.07	11.09	6.50	9.05
s <sub>x</sub>	1.01	1.92	1.47	1.73
2m $\bar{x}_2$	8.33	5.56	3.61	1.11
s	0.74	15.48	3.03	0.94
s <sub>x</sub>	0.50	2.27	1.01	0.55
3m $\bar{x}_2$	10.28	5.28	3.33	0.83@
s	17.57	6.46	4.89	--
s <sub>x</sub>	2.42	1.47	1.28	--
June 30				
0m $\bar{x}_2$	10.00	6.67	3.33	0.56
s	8.39	25.69	9.04	0.93
s <sub>x</sub>	1.67	2.92	1.73	0.55

## Appendix C. (Continued)

Transect	I	II	III	IV
1m $\bar{x}_2$	21.67	20.83	8.33	1.67
s <sub>2</sub>	81.25	21.60	4.92	2.77
s <sub>x</sub>	5.21	2.68	1.28	0.96
2m $\bar{x}_2$	25.56	21.67	19.44	0.84*
s <sub>2</sub>	92.50	18.75	17.22	1.39
s <sub>x</sub>	5.55	2.50	2.18	0.68
3m $\bar{x}_2$	29.17	28.89	15.83	4.17@
s <sub>2</sub>	77.68	1492.39	134.10	--
s <sub>x</sub>	5.09	22.33	6.69	--
July 5				
0m $\bar{x}_2$	230.83	45.56	28.61	3.33
s <sub>2</sub>	712.18	2260.98	479.29	9.04
s <sub>x</sub>	15.42	27.48	12.65	1.73
1m $\bar{x}_2$	223.61	128.33	87.50	7.78
s <sub>2</sub>	5508.43	1920.32	4341.49	162.72
s <sub>x</sub>	42.90	25.33	38.08	7.37
2m $\bar{x}_2$	188.61	113.89	70.55	11.67
s <sub>2</sub>	2918.22	664.10	905.68	352.62
s <sub>x</sub>	31.23	14.90	17.39	10.85
3m $\bar{x}_2$	120.00	86.38	43.89	1.67@
s <sub>2</sub>	23,549.78	23,504.29	83.44	--
s <sub>x</sub>	88.70	88.62	5.28	--
July 14				
0m $\bar{x}_2$	76.67	17.22	24.72	20.55
s <sub>2</sub>	1769.34	129.49	225.38	546.26
s <sub>x</sub>	24.31	6.57	8.68	13.51
1m $\bar{x}_2$	195.28	56.67	23.61	15.28
s <sub>2</sub>	6849.65	10.84	99.00	291.86
s <sub>x</sub>	47.84	1.90	5.75	9.87
2m $\bar{x}_2$	196.11	80.56	46.67	10.56
s <sub>2</sub>	19,278.79	31.75	1818.75	0.88
s <sub>x</sub>	80.25	3.25	24.65	0.54
3m $\bar{x}_2$	172.78	104.44	56.39*	5.00@
s <sub>2</sub>	6062.15	18.84	3073.38	--
s <sub>x</sub>	45.00	2.51	32.04	--

## Appendix C. (Continued)

Transect	I	II	III	IV
July 18				
0m $\bar{x}_2$	17.50	2.78	0.83	5.00
s	325.59	3.70	0.70	14.61
s <sub>x</sub>	10.43	1.11	0.48	2.21
1m $\bar{x}_2$	36.95	15.00	20.28	5.56
s	179.20	108.99	100.82	55.79
s <sub>x</sub>	7.73	6.03	5.80	4.31
2m $\bar{x}_2$	71.39	60.83	26.11	2.08*
s	405.80	719.58	295.99	3.18
s <sub>x</sub>	11.64	15.50	9.94	1.02
3m $\bar{x}_2$	112.78	98.89	16.39*	1.67@
s	2749.47	1614.79	264.12	--
s <sub>x</sub>	30.31	23.23	9.39	--
July 25				
0m $\bar{x}_2$	1.66	0.55	0.28	2.78
s	2.10	0.24	0.23	12.05
s <sub>x</sub>	0.83	0.28	0.27	2.01
1m $\bar{x}_2$	1.94	4.17	3.05	3.06
s	3.02	27.06	6.50	15.49
s <sub>x</sub>	1.00	3.01	1.47	2.27
2m $\bar{x}_2$	7.78	6.11	4.45	2.22
s	6.44	3.04	39.81	3.03
s <sub>x</sub>	1.46	1.01	3.64	1.01
3m $\bar{x}_2$	17.22	6.67	2.22	0@
s	115.66	11.09	5.80	--
s <sub>x</sub>	6.21	1.92	1.39	--
August 7				
0m $\bar{x}_2$	2.29	2.19	1.56	1.15
s	1.60	7.41	1.28	1.59
s <sub>x</sub>	0.73	1.57	0.65	0.73
1m $\bar{x}_2$	4.48	2.40	1.87	1.67
s	2.20	0.21	3.04	2.77
s <sub>x</sub>	0.86	0.26	1.01	0.96

## Appendix C. (Continued)

Transect	I	II	III	IV
2m $\bar{x}_2$	5.52	2.92	1.77	3.40
$s^2$	5.52	0.22	4.03	4.44
$s_x$	1.35	0.27	1.16	1.21
3m $\bar{x}_2$	9.58	4.48	5.00	1.01
$s^2$	51.03	2.49	0.42	0.04
$s_x$	4.13	0.91	0.37	0.12
August 15				
0m $\bar{x}_2$	0.62	0.31	1.25	0.42
$s^2$	0.30	0.01	0.40	0.52
$s_x$	0.31	0.06	0.36	0.42
1m $\bar{x}_2$	1.15	0.52	1.15	0.73
$s^2$	0.62	0.14	0.22	0.42
$s_x$	0.45	0.11	0.27	0.37
2m $\bar{x}_2$	1.67	1.15	2.19	1.77
$s^2$	0.13	0.82	5.08	0.91
$s_x$	0.21	0.52	1.30	0.55
3m $\bar{x}_2$	3.44	1.87	3.96	5.10*
$s^2$	0.28	0.69	11.34	39.17
$s_x$	0.30	0.48	1.94	3.61
August 27				
0m $\bar{x}_2$	9.48	6.98	3.75	0.10
$s^2$	61.80	1.64	3.83	0.04
$s_x$	4.54	0.74	1.13	0.12
1m $\bar{x}_2$	24.06	12.71	7.81	0.84
$s^2$	106.52	22.46	5.59	0.91
$s_x$	5.97	2.73	1.36	0.55
2m $\bar{x}_2$	16.67	10.42	7.61	0@
$s^2$	82.17	20.75	17.78	--
$s_x$	5.24	2.63	2.43	--
3m $\bar{x}_2$	19.58	17.92	10.21	0.94@
$s^2$	4.23	6.39	28.34	--
$s_x$	1.18	1.46	3.08	--
September 7				
0m $\bar{x}_2$	7.19	6.15	8.13	1.77
$s^2$	2.71	1.60	43.76	3.55
$s_x$	0.95	0.73	3.82	1.09

## Appendix C. (Continued)

Transect	I	II	III	IV
1m $\bar{x}_2$	12.40	8.54	8.23	2.30
$s^2$	32.20	21.26	52.14	3.63
$s_x$	3.28	2.66	4.17	1.10
2m $\bar{x}_2$	18.75	17.81	8.65	0@
$s^2$	71.08	21.31	17.28	--
$s_x$	4.87	2.66	2.40	--
3m $\bar{x}_2$	14.53	15.63	11.46	0@
$s^2$	8.24	2.66	1.15	--
$s_x$	1.66	0.94	0.62	--
Total				
0m $\bar{x}_2$	13.53			
$s^2$	1312.23			
$s_x$	5.46			
1m $\bar{x}_2$	23.48			
$s^2$	2254.81			
$s_x$	7.16			
2m $\bar{x}_2$	25.19			
$s^2$	1990.48			
$s_x$	6.73			
3m $\bar{x}_2$	24.72			
$s^2$	1576.61			
$s_x$	5.99			